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THE HISTORY OF THE CALORIE IN NUTRITION

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THE nomenclature of a science is of vital importance; it is intimately bound up in the subject itself. Special technical words are used to describe the phenomena which are being studied. Lavoisier emphasized the importance of nomenclature in his "Traité Élémentaire de Chimie" (1789) when he stated: "Every branch of physical science must consist of three things; the series of facts which are the objects of the science; the ideas which represented these facts, and the words by which these ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea, and the idea to be a picture of the fact . . . ; we can only communicate false or imperfect impressions of these ideas to others, as long as precise terms are lacking."

The calorie as defined in the science of nutrition is a measure of food value. The significance of the word calorie as thus used to-day is not the same as its import when first introduced into the French language. To the student of nutrition the word connotes something quite different from the term as employed by the physicist. It is the amount of a food substance which on combustion in the body will yield energy—heat or work—equivalent to a calorie as understood by the physicists. Even the term as employed by the latter to-day has undergone a change from its original meaning (1845). As first defined the calorie represented the amount of heat required to raise one *kilogram* of water through one degree centigrade. It is well known that the same term now means the amount of heat required to raise one *gram* of water through one degree centigrade. The calorie, then, has had—and still does have—two somewhat unlike meanings according as the gram or kilogram of water is the unit of mass, the temperature of which is being changed and the energy required for this change is being considered. Both of these meanings are preserved in the scientific literature of to-day, the larger unit being designated as a large calorie and written Calorie.

It is quite evident that either the small calorie or the large Calorie may be the more convenient unit with which to express heat change depending upon the magnitude of the change being studied. The physicist in expressing the amount of energy supplied in the form of heat required to raise one gram of water from its freezing point to its boiling point obviously is dealing with a relatively small energy change which if expressed in heat units, as discussed above, is in the neighborhood of one hundred calories. In such cases the little calorie is the convenient unit to employ; on the other hand experiments in the field of nutrition have demonstrated that the energy changes are of such magnitude that the Calorie is the more convenient unit for expressing them quantitatively.

The derivation of the word is very interesting; it has developed from the old French word "calorique" which was derived from the Latin term "calor." Lavoisier introduced "calorique," which was defined at that time as an elastic fluid containing the hidden cause of the sensation of heat and to which the phenomena of heat were attributed. This meaning was abandoned with the theory to which it belonged. As far as a review of the literature reveals Bouchardat (1845) was probably the first to define it according to the modern physical conception. In his "Physique élémentaire" we read: "Unité de chaleur—On designe sous le nom d'unité de chaleur ou de calorie celle qui est nécessaire pour élever 1 kilogram d'eau d'un degré du thermomètre centigrade."

The idea of measuring heat in this way had been in general use for some time, but the word calorie had not been introduced earlier.

Pouillet (1832) in his "Physique" defined the heat liberated by combustion of different substances as "Élévation de température que 1 gr. de chaque substance en se brûlant avec l'oxygène communiquerait à 1 gr. d'eau." He ascribed the value 6195° to alcohol which checks closely with its caloric value as now known. Although the French had coined the word in the year 1845, it apparently was not in general use for some time; for in 1852 Favre and Silbermann¹ in an article on heat wrote: "We shall repeat that the unit which we have adopted is that adopted by all physicists, that is, the quantity of heat necessary to raise 1 gram of water 1 degree and which they call unit of heat or calorie." The Germans evidently took the word from the French, but it is difficult to determine at what time. Gmelin (1817-19) in his

¹ Favre and Silbermann: *Ann. de chim. et phys.*, 1852, Ser. 3, xxxiv, 357.

"Handbuch der Chemie" uses the same idea as the calorie unit but refers to it as did Pouillet. As late as 1871 Senator² deemed it necessary in an article on heat production and metabolism to define the word "calorie" in a footnote.

According to a contributor to Murray's "New English Dictionary on Historical Principle" (1888), the word calorie was first introduced into English in 1870 by T. L. Phipson in his translation of "The Sun" by the French astronomer, Amédée Guillemin. Before this time the English had spoken of heat units which referred to Joule's mechanical equivalent of heat, *viz.*, 1 kilog. of water raised 1°C=423 metrekilogs. This was the term used in Frankland's³ classic treatise "On the Origin of Muscular Power."

The derivation of the word calorie has not revealed its meaning; for that it is necessary to consider the history of animal heat, combustion and the potential energy of the foodstuffs. To the old scientists animal heat offered a difficult problem, surrounded with much mystery. They could not explain it by any known chemical or physical laws. They did not assign any cause to it, but described it as an innate quality, something "vital" situated in the heart and distributed to the body by the blood vessels (Plato, Aristotle, Galen). The principal function of the blood was to distribute the heat, while the great function of respiration was to cool this distributing medium. Mechanical and chemical notions were accorded to heat production. As a history of the calorie is concerned only with the chemical theories, the mechanical ones described by Haller (1757)⁴, Boerhaave (1709)⁵ and contemporaries will not be discussed here. Willis (1670)⁶ was probably the first to consider an idea of combustion in heat production. He said that there was a "combustion" in the blood dependent upon fermentation excited by the combination of different chemical substances. All the chemists of the time considered animal heat a product of a "fermentation" occurring in the blood while in the heart. Willis' term "combustion" was not in accord with the modern conception in which oxygen is essential, as this element had not been discovered. A more correct opinion was enunciated by Mayow (1674)⁷ who had experimented on the elements of the

² Senator: *Centralbl. f. d. med. Wiss.*, 1871, IX, 737, 753.

³ Frankland: *London, Edinburgh, and Dublin Phil. Mag. and Jour. of Sc.*, 1866, xxxii, 182.

⁴ Haller: "Elementa Physiologiæ," 1757.

⁵ Boerhaave: "Aphor. cum Notis Swieten," pp. 382-675.

⁶ Willis: "De Accensione Sanguinis," 1670.

⁷ Mayow: "Tractatus Quinque," Oxonii, 1674.

air and described a "nitro-aerial spirit" (oxygen). He held that the function of respiration was not to cool the blood but to enable this fluid to absorb nitro-aerial gas for generating heat. Mayow's theory did not appear to make any considerable impression upon his contemporaries. It was not until Joseph Black's (1755)⁸ experiments on fixed air were performed that more correct ideas prevailed. He showed that the gas expired from the lungs is the same as that produced by combustion of fuel, thus establishing a relationship between combustion and respiration. Black was forced to relinquish his theory by his contemporaries who claimed that if the lungs were the sole seat of combustion the amount of heat produced therein would be so great that the vitality of the organ would be destroyed.

The production of heat by a combustion of foodstuffs was merely suggested at this time (1677) with no air of conviction that such could be the case. It appears that Descartes should receive the credit for first suggesting the correct theory regarding heat production in the animal body in his "De Homine" (1662). He thought that the change produced in the food in the stomach was analogous to the heat produced when water is poured upon lime or aqua fortis on metals. Hunter (1761) in his dissertation "On Blood" incidentally remarks that "the source of heat is in the stomach." He had previously expressed dissatisfaction with all prevailing theories of animal heat. Hunter's idea is to be regarded merely as his suggestion, with as yet no clear-cut data to justify its assumption of the rank of an established theory.

It remained for Lavoisier, the father of modern chemistry, to prove by his carefully performed experiments that animal heat is not caused by any mystical "vital force" as the ancients believed, but is a phenomenon analogous to the burning of a candle, namely, the combustion of carbon. He repeated, verified and added experiments to those of Black and Priestley, and explained more explicitly than had ever been done before the source of animal heat. In 1780 in his "Mémoire sur la Chaleur" published in collaboration with Laplace he gave in detail the theory of heat essentially as we have it to-day. By means of the calorimeter the heat evolved during the formation of a definite quantity of carbonic acid was compared with that produced during the formation of the same amount of this compound during respiration. These investigators saw that in such transformations identical amounts of heat were produced. They concluded that animal heat is derived from the oxidation of the body's substance.

⁸ Robison: "Joseph Black," Edinburgh, 1803.

The publications of Lavoisier's time and before that had spoken of heat as "chaleur." Pouillet (1832), the physicist, remarked: "Scientists confused the cause of heat with its effect. They called it chaleur, fluide igné, matière du feu. Finally in reforming the chemical nomenclature Lavoisier, Bertholet, Morveau and Foureroy have called it calorique. This term was adopted by the physicists of the time; and they reserved the word 'chaleur' to designate the science which treats of the properties, effects and laws 'du calorique.'"⁹ An interesting use of "calorique" is found in the "Mémoire sur la Respiration des Animaux" published in 1789 by Lavoisier and Seguin. They state, "1. Que le calorique (matière de chaleur) est un principe constitutif des fluides (Sous ce nom générique nous comprenons les airs et les gaz.) et que c'est à ce principe qu'ils doivent leur état de'expansibilité, leur élasticité, et plusieurs autres des propriétés que nous leur connaissons."¹⁰ There is no reference to a heat unit, calorie, in Lavoisier's publications. He defines the amount of heat in terms of the weight of ice melted in a given experiment.

Although the early physiologists suggested the correct source of animal heat, it is significant that they considered heat a simple chemical reaction, as stated by Descartes. Apparently they had no idea of a combustion as understood in the modern sense occurring in the tissues, for they did not consider the source of animal heat in starvation. Even physiologists of 1803 like Richerand do not consider starvation in their texts.

Lavoisier taught us the true cause of animal heat, but he could not explain the theory as to-day because the law of the conservation of energy had not been formulated. Joule (1844) by his masterly researches evaluated the mechanical equivalent of heat, and largely on this basis Mayer (1845) gave expression to the law of conservation of energy, the application of which was made by Helmholtz. Energy cannot be destroyed or created. As even the ancient Greek Democritus (370 B. C.) once said, "Nothing can ever become something nor can something become nothing"—*ex nihilo nihil fit, et in nihilum nihil potest reverti*.

Dulong, Depretz, Regnault, Reiset, Pettenkofer and Voit contributed considerable to the study of animal heat and in turn helped to perfect the calorimeter. It remained for Rubner¹¹ to

⁹ "Chaleur" probably would be translated thermodynamics and "du calorique" heat.

¹⁰ Lavoisier et Seguin: "Mémoire sur la Respiration des Animaux," 1789.

¹¹ Rubner: *Zeit. f. Biologie*, 1883, xix, 313; 1885, xxi, 250; 1886, xxii, 40; 1894, xxx, 73.

prove that physiological activity in the animal body is no exception to the operation of the law of conservation of energy. He showed that chemical change is the cause of animal heat. He discovered that the animal is a living calorimeter in which food, when burned, changes into another form of energy. Rubner, experimenting with dogs, measured the body's income and output of energy, and determined the relation of heat produced by oxidation of the foodstuffs ingested to the products which are given out. This figure he compared with the energy produced as measured by the calorimeter and found an agreement within one per cent. This remarkable result has since been confirmed by other investigators who have been aided by modern methods, the refinements of which are difficult to describe adequately. Rubner's important conclusions are that energy is not destroyed or created by the living organism; that the foodstuffs are oxidized within the body in a manner similar to their oxidations in a chemical laboratory. The law of conservation of energy therefore applies to the animate as well as to the inanimate world.

When calories are mentioned in nutrition, it is from the point of view of food fuel value. The calorie value of a diet is a factor of great importance in nutrition. Frankland (1866) was the first to determine this for various foodstuffs by oxidizing them in a calorimeter. He did not express the results in "calories" but rather as "heat units" (*loc. cit.*) which had the same value. Stohmann (1879)¹² and Rubner (1883) were apparently the first to use the term calorie as it is now applied in the science of nutrition. Rubner made three outstanding contributions regarding the calorie in nutrition: (1) He applied its present day meaning to the term; (2) he determined the caloric value of protein, fat and carbohydrate, figures which are widely used in determining the energy content of a diet; (3) he drew the distinction between the absolute and physiological heat values of foods. By absolute heat value he meant the amount of heat yielded by a substance when oxidized in a bomb calorimeter; the amount of heat produced by the substance in question when burned within the animal body he regarded as its physiological heat value. These values may or may not be identical, a fact which is of fundamental importance in the science of nutrition.

Calorie as a mere word explains nothing. It is a symbol for an idea, however, which, as we have seen, has undergone changes brought about by the development of several sciences. Ancient

¹² Stohmann: *Journ. f. prakt. Chem.*, 1879, xix, 115.

and hazy notions regarding the phenomenon of fire and combustion first contributed to this concept, placed on a firmer foundation by the clarifying influence of Lavoisier. The broad generalization regarding force in nature, receiving its impression in the law of the conservation of energy, played its rôle in the evolution of the idea and should probably be regarded as the most important factor contributing to the development of this notion as it exists to-day. The history of the calorie in nutrition, therefore, is wrapped up in the history of nutrition itself and the fundamental natural sciences upon which this branch of knowledge rests.